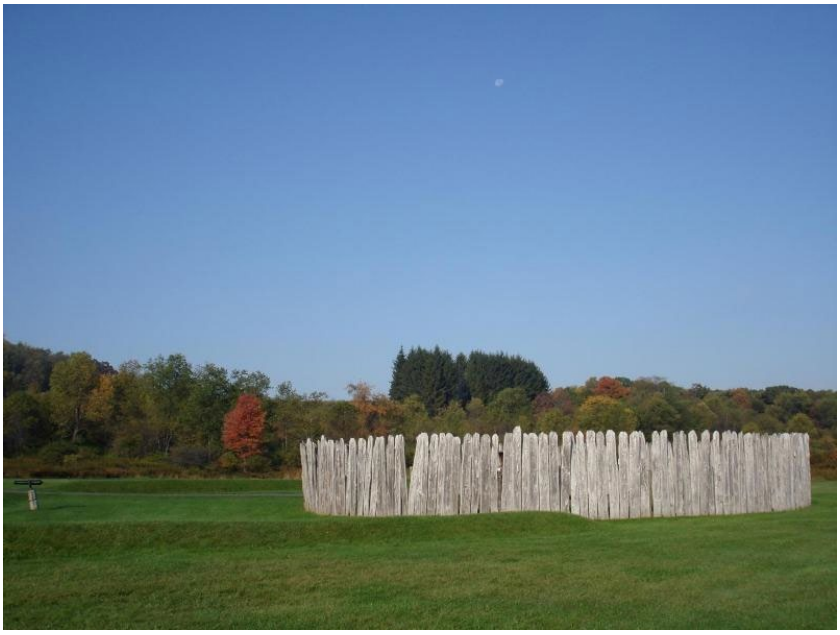
Biological Evaluation of Eastern Hemlock, at Fort Necessity National Battlefield, Fayette County, Pennsylvania



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Abstract

During the winter of 2014 and 2015 personnel from the USDA Forest Service, Northeastern Area, Forest Health Protection, Morgantown, WV Field Office conducted a survey to evaluate hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Hemiptera: Adelgidae), population densities along the roads and trails at Fort Necessity National Battlefield in southwestern Pennsylvania. The purpose of the survey was to assess the need for treatment of hemlock trees within view of visitors at the battlefield. Since HWA is present throughout much of Pennsylvania, it was important to survey the areas accessible to visitors, and determine whether HWA had established in the park.

Purpose and Need

The Morgantown Field Office received a request for a site visit from MaryEllen Snyder, Management Assistant of the Western Pennsylvania Parks, National Park Service to access hemlock woolly adelgid activity within Fort Necessity National Battlefield. This project was undertaken by the MFO to address this request and to survey eastern hemlock trees (*Tsuga canadensis* (L.) Carriére) within the park.

Project Location/Description

The Fort Necessity National Battlefield Park (FONE) is located in southwestern Pennsylvania in Fayette County (39.810467N, -79.590363W). The battlefield was designated as a National Battlefield Site by the United States War Department on March 4, 1931(Perles et al., 2006). The land was transferred to the National Park Service on August 10, 1933 and was designated a National Battlefield on October 26, 1974 (Perles et al., 2006). The park preserves the land on which the opening engagement of the French and Indian War occurred (Harrington, 1954), and two other sites. The FONE unit is composed of three areas: Fort Necessity, Braddock's Grave, and Jumonville Glen which combined cover approximately 908 acres of which 712 acres are forested (Figure 1).

The Park lies in the mixed mesophytic forest type (Rhoads and Block, 2005) within the Central Appalachians US EPA Level III ecoregion (http://www.cec.org/ecosystems). These forests were once dominated by the American chestnut (*Castanea dentata* (Marshall) Borkh.) but now contain a mixture of chestnut oak (*Quercus prinus* L.), red maple (*Acer rubrum* L.), white oak (*Q. alba* L.), black oak (*Q. velutina* Lam.), American beech (*Fagus grandifolia* Ehrh.), yellow-poplar (*Liriodendron tulipifera* L.), sugar maple (A. sacharum Marshall), ash (*Fraxinus* L.), basswood (*Tilia* L.), buckeye (Aesculus L.), and eastern hemlock (Wiken et al., 2011).

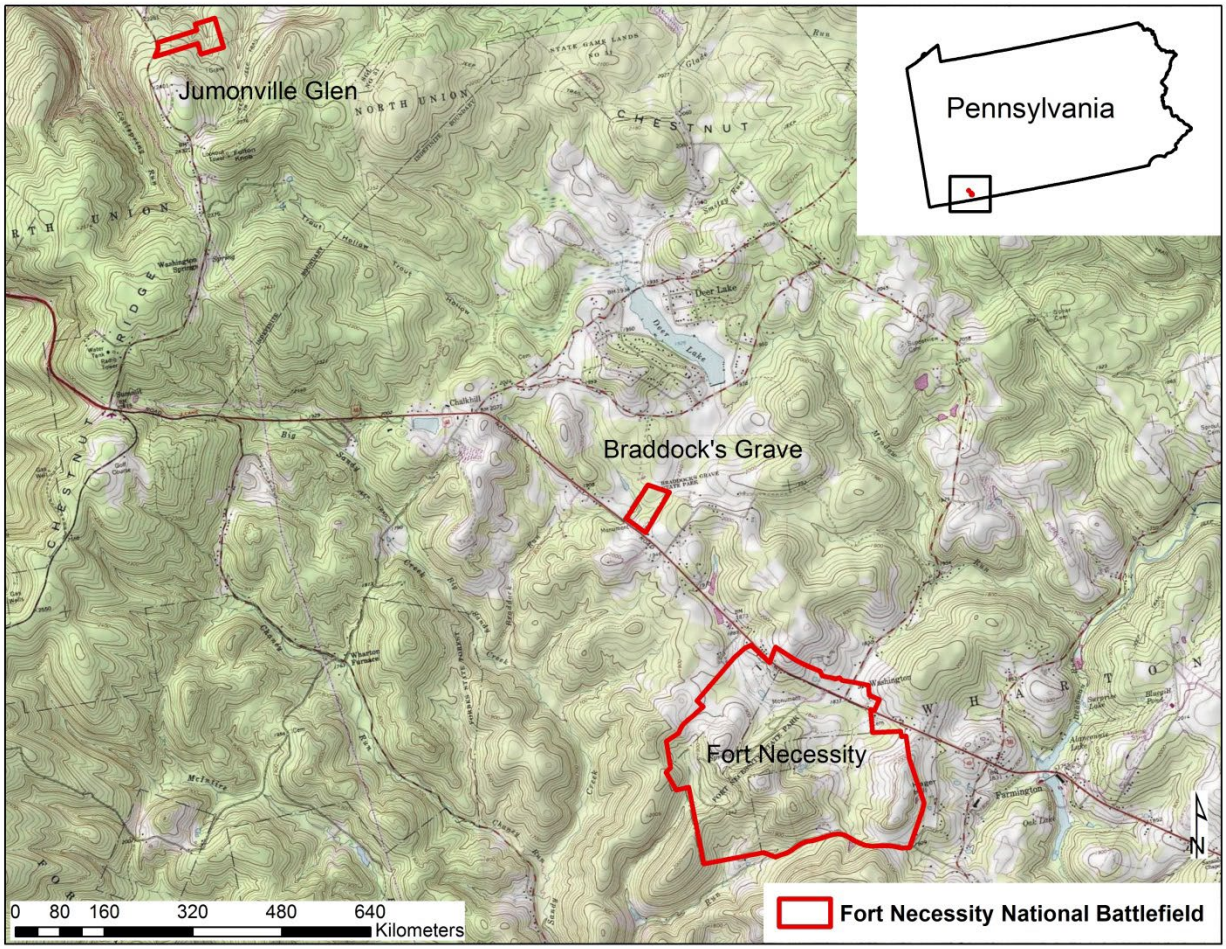

Figure 1. Jumonville Glen, Braddock's Grave and Fort Necessity National Battlefield, Fayette County, Pennsylvania.

Project Objectives

The objectives for this evaluation were to 1) determine whether or not HWA was present and active within FONE, 2) assess the location of eastern hemlock (*Tsuga canadensis*) at each of the park areas Fort Necessity, Braddock's Grave, and Jumonville Glen, 3) inventory the physical characteristics of the trees that are within sight from roads and trails, and 4) determine the need for management activities within the three park units at Fort Necessity National Battlefield.

Project Methods

ARCMAP data

We used ARCMAP® data provided by U.S. Department of the Interior; National Park Service to identify the administrative boundary area, roads, trails and other park features. These features were then overlaid with National Agricultural Imagery Program (NAIP) data, NPS vegetation data, and leaf-off Google earth imagery, which were used to digitize conifer tree cover, calculate

acreage, and identify tree positions and survey areas. In addition we used United States Forest Service Forest Health Technology Enterprise Team (FHTET) 30 meter resolution eastern hemlock host data (http://www.fs.fed.us/foresthealth/technology/) to help identify the location of eastern hemlock occurrence within FONE (Figure 2).

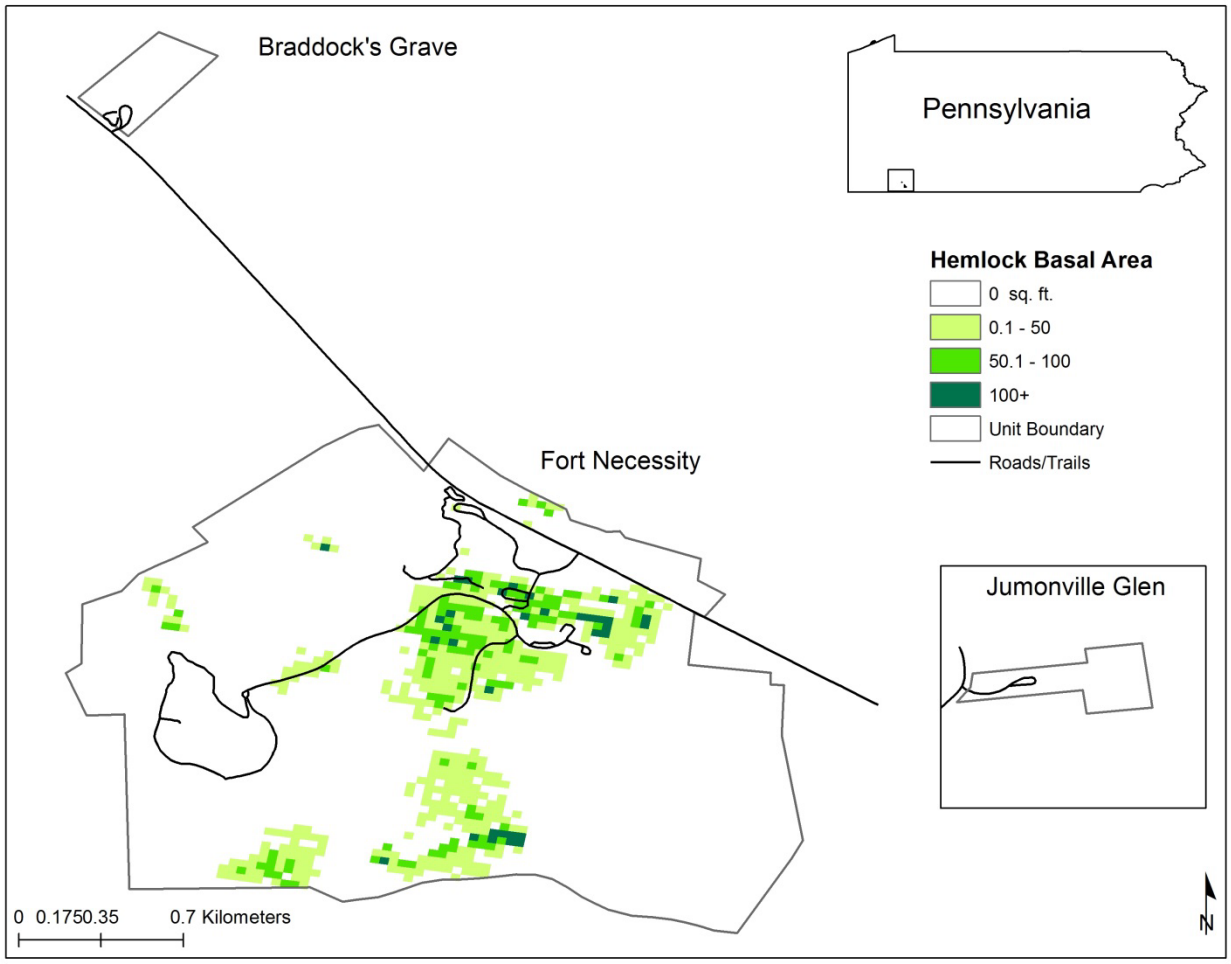

Figure 2. Forest Health Technology Enterprise Team (FHTET) model for eastern hemlock basal area, measured in square feet per acre.

The information used in this hemlock host layer was gathered from satellite imagery and Forest Service Forest Inventory and Analysis data. These data were then modeled to create a 30-m^2 grid map representing the amount of hemlock basal area predicted to be present within FONE (figure 2).[1] Note that the darker the shading in figure 2, the greater the amount of hemlock basal area predicted to be present.

Inventory areas and tree assessment

In the fall and winter of 2014 and 2015, MFO staff conducted an intensive hemlock inventory of

[1] Basal area is a common term used to describe the amount of area occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height (4.5 ft. above the ground) (U.S. Department of Agriculture 2001) and is expressed as per unit of land area (typically square feet per acre).

FONE (figure 3). To survey for the presence of HWA, we used the FHTET eastern hemlock basal area model, roads and trail to identify survey areas. To reduce our survey further we created 100 ft. buffers around all roads and trails within the park. These buffer areas were then surveyed for eastern hemlock trees. Tree data was collected on all trees at least 3.0 inches in diameter at breast height (dbh; 4.5 ft. above the ground; USDA 2001). For each tree (≥ 3.0 inches dbh) we recorded crown class (i.e. dominant, co-dominant, intermediate, and overtopped; USDA 2001), visible tree damage (e.g. conks, cankers, wounds, cracks, etc.), diameter at breast height (dbh), indications of HWA infestation, presence of new growth, and whether the tree was visible from roads and trails. Each hemlock was tagged with a unique number using blue aluminum tags and aluminum roofing nails. GPS coordinates were also taken of each tree using a handheld Trimble GPS device and mapped using ArcGIS.

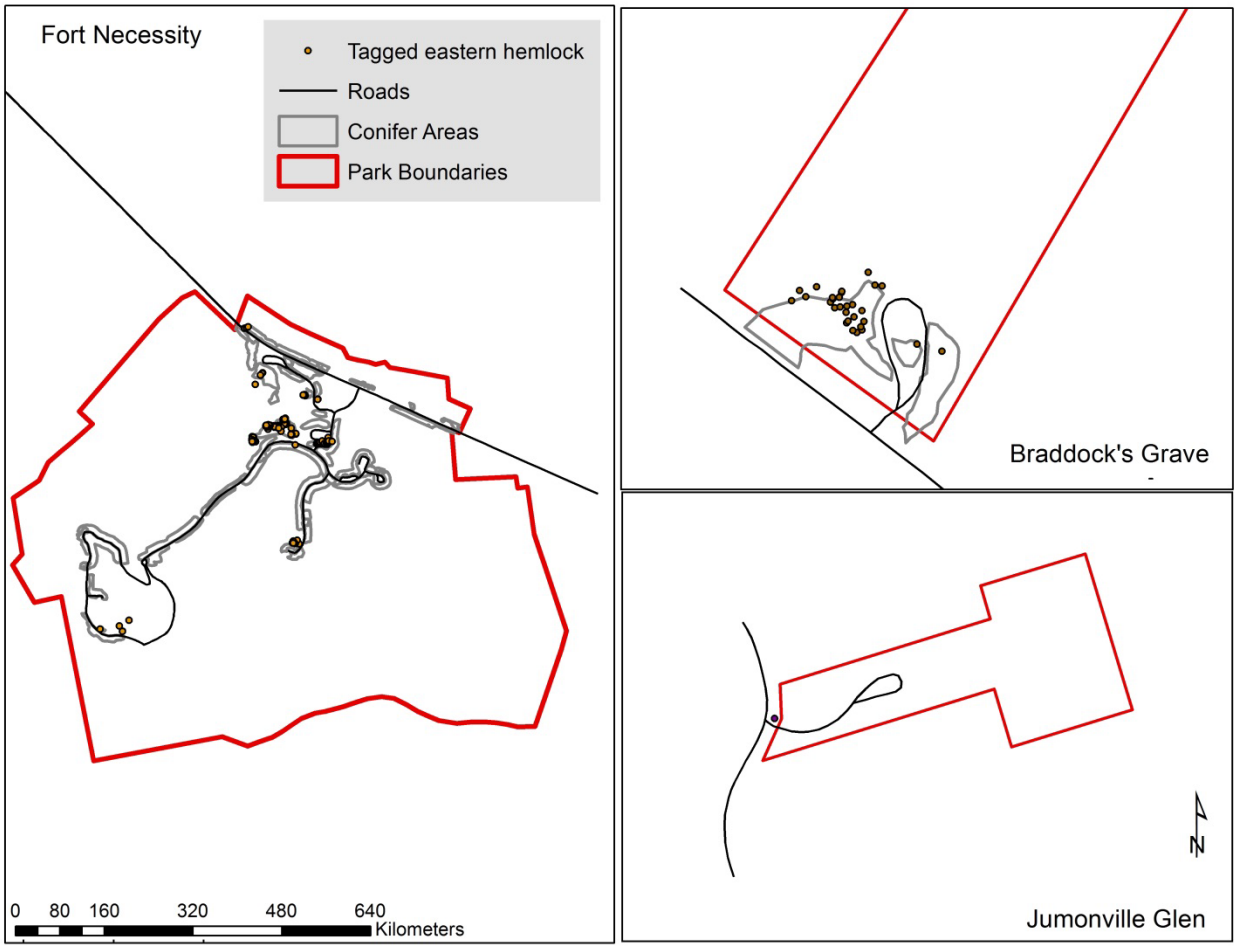

Figure 3. Tagged Hemlock Trees within Conifer Area near the Visitor Center and Braddock's Grave, Fort Necessity National Battlefield, Fayette County, Pennsylvania.

Results

The hemlock woolly adelgid was not found to be present at FONE. In the three areas of FONE, 118 eastern hemlock trees were tagged, measured and assessed (Table 4). The average d.b.h. for

hemlock trees was 12.0 ± 5.0 inches; trees ranged in size from 5.0 to 34.0 inches d.b.h. All the hemlock trees surveyed appeared in good health, with no defects or dieback noted.

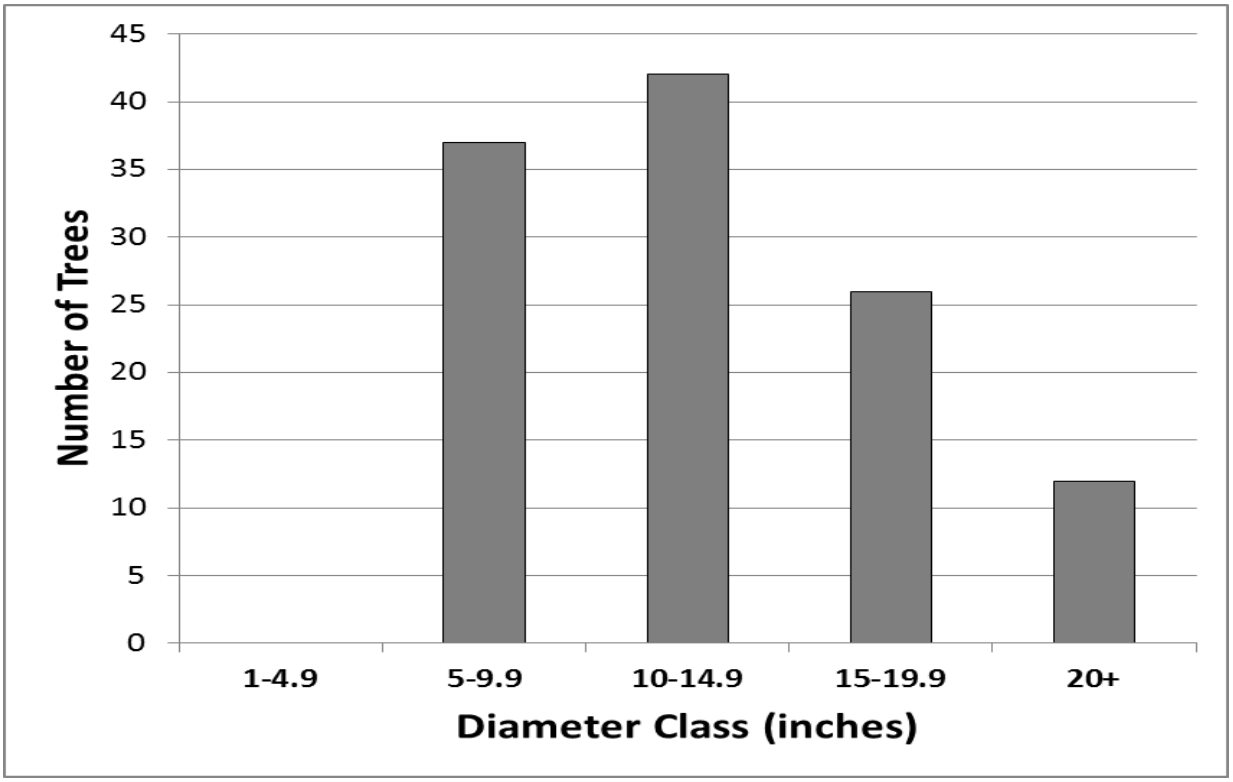

Figure 4. Size distribution of eastern hemlock at Fort Necessity National Battlefield, Fayette County, Pennsylvania.

How come no trees >5 inches dbh? Was there any regeneration of hemlock present? Deer, NNIS etc need to flesh out….

Table 1. Number and crown positon of eastern hemlock visible from trails or roads at Fort Necessity National Battlefield, Fayette County, Pennsylvania.

Area	Visible from Trails or Roads		Crown Position of Visible Trees			
	Yes	No	Dominant*	Co-dominant	Intermediate	Overtopped
Fort Necessity	82	5	43	17	21	6
Braddock's Grave	30	0	2	13	13	2
Jumonville Glen	1	0	0	1	0	0
Total	**113**	**5**	**45**	**31**	**34**	**8**

*Includes open grown

Project Discussion

The main objectives for this evaluation is to determine the presence of hemlock woolly adelgid, inventory the area, and evaluate the need for management activities at the FONE. Fortunately, HWA was not detected and no wide-scale mortality or decline was observed during this survey.

Currently, the only available options for protecting eastern hemlock from HWA are individual tree chemical treatments. Treatments are limited by the biology and feeding behavior of HWA, its population densities, the site conditions (i.e. proximity to streams), accessibility and the limited application technology currently available. Insecticide treatments are effective, although they are conducted on an individual tree basis and can be both labor intensive and costly. Thus treatment strategies are typically focused in high value sites such as recreational or scenic areas. Classical biological controls such as predators and pathogens are being pursued by the USDA Forest Service but will likely take years to become effectively established. As such, preservation of hemlocks at the FONE will require intensive monitoring and an aggressive chemical treatments strategy. Since HWA has not been found within the area it is recommend the NPS staff be trained to identify HWA, and yearly individual tree surveys of the tagged eastern hemlock trees be performed by local staff.

Species Evaluation

Hemlock Woolly Adelgid

The hemlock woolly adelgid is believed to have been introduced into the eastern United States from Japan (Havill and Foottit. 2007) sometime before 1951 on nursery stock. It was first discovered on eastern hemlock trees in a municipal park that had previously been a private estate (Souto et al. 1996, Ward et al. 2004). Over the next 30 years HWA slowly spread through the Mid-Atlantic States (Souto et al. 1996). By the late 1980s and 1990s HWA population had expanded rapidly and was reported to be causing widespread mortality (Cheah et al. 2004). HWA is currently established in 19 eastern States from Georgia to Maine.

Life Cycle

The hemlock woolly adelgid has a complex life cycle involving both sexual and asexual stages on both spruce and hemlock (figure 5; McClure 1989). The life cycle on eastern hemlock is bivoltine including a “sistens” or wingless winter generation that starts in late spring and lasts for 9 to 10 months (McClure

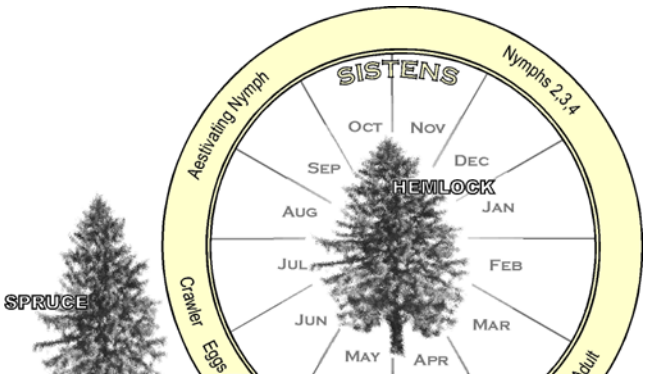

Figure 5. Life cycle of the hemlock woolly adelgid on hemlock in North America (Ward et al. 2004)

1989) and a "progrediens" or spring generation that starts in the early spring. The progredien generation is composed of both winged (sexuparae) and wingless offspring and lasts for about three months (Ward et al. 2004). The winged generation is the sexual migratory stage which leaves hemlock to find spruce (McClure 1987). The percentage of the population of progrediens is strongly density dependent; as the tree health declines and preferred feeding sites (new growth) is reduced the percentage of winged adults increases (McClure 1991). Because of the lack of a suitable primary host a spruce species (Tiger-tail spruce, *Picea torano* K. Koch) in the eastern United States the production of the winged form results in a substantial loss of individuals from the spring generation (McClure 1989, Havill et al. 2014). HWA has a high reproductive potential with each adult producing up to 300 eggs (McClure et al. 2001). The eggs hatch into first instar mobile crawlers, which are active for one to two days, before settling or being dispersed (McClure 1987, Ward et al. 2004). Once settled the nymph inserts its stylet and feeds on the xylem ray parenchyma cells at the base of the hemlock needles (Young et al. 1995). The adelgid then develops through four instars before becoming an adult (McClure 1989).

Feeding Impact

The combination of two annual generations, a high reproductive capacity, and the lack of natural enemies (Van Driesche et al. 1996, Wallace and Hain 1998, Cheah et al. 2004) gives HWA the ability to increase rapidly in numbers (McClure 1989). Feeding can quickly lead to needle loss, dieback and mortality (Cheah et al. 2004) and appears to induce a hypersensitive response in the tree (Radville et al., 2011). Although the exact physiological effect of HWA feeding on hemlock is not well understood, feeding by the adelgid, impacts the uptake and movement of water (McClure 1995, Domec et al., 2013), and reduces the trees energy reserves (Ward et al. 2004) which can lead to tree mortality in 4-7 years (Orwig and Foster 1998, McClure et al. 2001), although some trees can last more than 15 years (Souto et al. 1996, Paradis et al. 2008, Havill et al. 2014). Other stress factors such as weather, site conditions, stand overstocking, and defoliation, can intensify the impacts of HWA (Havill et al. 2014). All life stages of hemlock, from seedling to mature old-growth trees are fed upon (McClure 2001).

Dispersal and Spread

The hemlock woolly adelgid spreads mainly as eggs and crawlers which are transported by wind, birds, deer, and other forest-dwelling mammals (McClure 1990, Cheah et al. 2004, Ward et al. 2004). It can also be moved on infested nursery stock or during logging and recreational activities (McClure 1995, Gibbs 2002, Ouellette 2002). Roads, hiking areas and riparian areas have all been implicated in the long-distance spread of the adelgid by humans and birds (Koch et al. 2006). Recent evidence suggests that the current rate of spread is between 8-16 km per year (Evans and Gregoire 2007). As of 2011, 47 % of the native range of eastern hemlock is infested with HWA (A. Steketee, USDA Forest Service, personal communication).

Eastern Hemlock

Eastern hemlock, *Tsuga canadensis* (L.) Carriére, is an extremely shade-tolerant, monoecious, slow-growing, late successional conifer with a dense, evergreen crown and that strongly influences its environment and other species (Ward and McCormick 1982, Godman and Lancaster 1990, Evans et al. 1996, Quimby 1996, Evans 2000). Eastern hemlock has a conical crown with horizontal-to-pendulous branches (Ruth 1974) and 2-ranked needles (Dirr 1998). It exhibits relatively low branch shedding (Kenefic and Seymour 2000), and retains its needles for an average of three years (Barnes and Wagner 1981).

Eastern hemlock is a relatively long-lived species with a life span of over 800 years (Godman and Lancaster 1990). Seed production usually begins when trees are 20-30 years of age (Ruth 1974). It is a frequent and abundant cone producer (Crow 1996), with good crops being produced every 2 to 3 years (Frothingham 1915, Ruth 1974).

Native Range

Eastern hemlock is widely distributed in North America from Nova Scotia across southern Ontario to northern Minnesota, and south to Alabama along the Appalachian Mountains (Brisbin 1970, Godman and Lancaster 1990, Quimby 1996). Hemlock generally grows in areas with cool humid climates (Godman and Lancaster 1990, McWilliams and Schmidt 2000). Annual precipitation ranges from 74 cm to more than 127 cm across the range of eastern hemlock (McWilliams and Schmidt 2000). It grows at elevations from sea level to 730 m in the northeastern and northern areas, from 300 to 910 m on the Allegheny Plateau and from 610 to 2036 m in the southern part of its range (Hough 1960, Eyre 1980, Godman and Lancaster 1990).

Growth and Associated Species

Hemlock can occur in pure stands (Eyre 1980), or mixed with other species. On favorable sites, it usually forms a climax position (Brisbin 1970) while on sites with rich in nutrients, it can be out competed by hardwoods (Kotar 1996). In pure stands, undergrowth vegetation can be sparse (Eyre 1980) due to intraspecific allelopathy (Ward and McCormick 1982) and to the dense evergreen crown of hemlock which intercepts both light and precipitation. Because of this dense canopy in hemlock stands the microclimate is cooler than under hardwoods (Tubbs 1996). This distinct microclimate provides an important habitat for a wide variety of wildlife (Evans 2000). In the northeastern United States 96 bird and 47 mammal species have been found to be associated with eastern hemlock forests (Yamasaki et al. 2000). This includes 23 species of small mammals, 14 species of wide ranging carnivores, 10 species of amphibians, and 7 species of reptiles (Degraaf et al. 1992). Hemlock forests can also be a critical factor in the support of native brook trout populations, where it maintains cool stream temperatures and stabilizes stream flows (Evans et al. 1996, Quimby 1996). Eastern hemlock fills a unique ecohydrological role

because it transpires throughout the year and it provides stable water fluxes within a watershed and high water flux patterns in the spring, reducing nutrient loss and decreasing watershed discharges (Ford and Vose 2007).

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